The Effects of Climate Change on Behavior of Tropical Flats Fishes

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Introduction

Climate Change

Climate change is a shift in the global mean temperature and associated weather patterns. As the ocean temperature increases, salinity and acidity increase as well (Pörtner & Farrell 2008). In the past 100 years, global mean air temperatures have increased by 0.7° C and in the next 20 years, they are expected to increase by 0.4° C (Nurse 2011). This warming is thought to be caused by an increase in atmospheric greenhouse gases, particularly CO_2, due to the relatively recent increase in the burning of fossil fuels. CO_2 in the atmosphere dissociates with water to make carbonic acid, thus raising the acidity of oceans regionally.

The Flats Ecosystem

Tropical flats ecosystems are complex ecosystems made up of sea grass beds, mangroves, and sandy flats. The species living within are both ecologically and economically important to the Bahamas. snapper and mojarra are consumed in the Bahamas, and bonefish are economically valuable, as tourism based on bonefishing brings in $141 million dollars to the Bahamian GDP annually (Danylchuk et al. 2007). Additionally, bonefish participate in nutrient cycling through predator-prey relationships (Danylchuk et al. 2007). Tropical flats fish are more susceptible to the effects of climate change than temperate fish because they have not adapted to cope with the seasonal variations in climate that temperate fish experience (Huey & Tewksbury 2009).

Purpose

Our study specifically involves checkered puffer (*Sphoeroides testudineus*), schoolmaster snapper (*Lutjanus apodus)*, yellow-fin mojarra (*Gerres cinereus*), and monefish (*Albula vulpes*). The purpose of the experiment was to determine at what pH a fish will choose to leave a given environment for a new one. The study also tested at what point a fish will choose to risk a higher chance of predation in order to avoid increasing acidity. Our hypotheses were that the species of fish tested here would demonstrate different avoidance thresholds for water pH, and that fish would remain in unfavorable conditions longer to minimize the risk of predation..

Methods

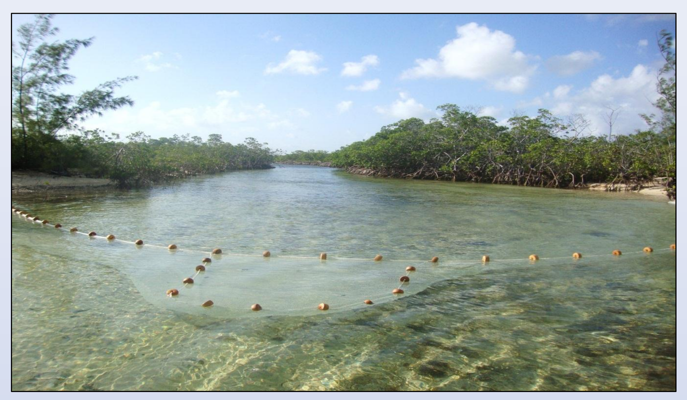

Fig. 1. Seining for bonefish at Airport Flats

Fig.2. Hand-lining for snapper

All of the fish used during the trials were collected by seining, a technique that involves setting a seine net at the mouth of the creek and scaring the fish down and into the net where they can then be collected (Fig. 1) Lemon sharks were also collected for use in predator trials. Some of the snapper were obtained through hand-lining (Fig. 2), where small bits of fishing line were fitted with hooks and bait. The hand lines were then used in shallow creeks to catch the fish. All fish were transported from collection locations back to the Cape Eleuthera Institute Wetlab in 45 L plastic totes, and water changes were conducted every two minutes (Fig. 3).

Fig. 3. Fish were obtained at three separate sites across South Eleuthera, The Bahamas. Fish were collected at Page Creek (a), Bottleneck Creek (b), and Airport Flats (c). Star depicts location of the Cape Eleuthera Institute.

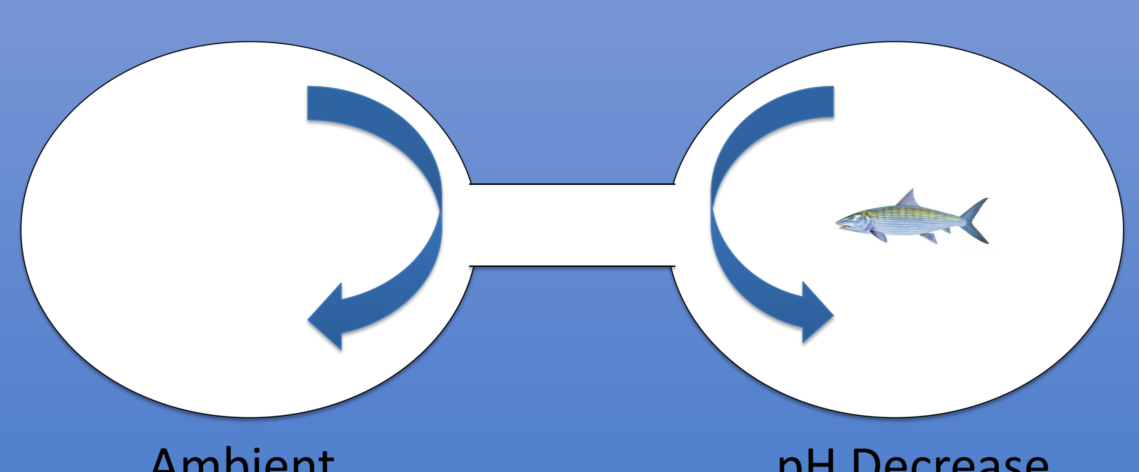

Fig. 4. Shuttlebox schematic. Carbon dioxide was controlled electronically, and bubbled in to decrease pH in the manipulated tank. Arrows indicate direction of recirculation for each side of the shuttlebox.

Shuttlebox trials were conducted at the CEI wetlab to test water pH thresholds of checkered puffer, bonefish, yellowfin mojarra, and schoolmaster snapper (Fig. 4). Before each trial, each fish was acclimated to the shuttle box for 20 minutes. At the start of the trial, the pH was lowered by 0.1/minute in one tank. The other tank was kept at ambient seawater conditions. PH was monitored throughout, stressed behavior (e.g., erratic swimming, gulping) was recorded, as was the the pH of shuttle (when fish switched sides). The trial ended after the fish remained in ambient conditions for 4 minutes. During predator trials, a lemon shark was introduced to the ambient side of the tank and then the trial was conducted normally.

Results

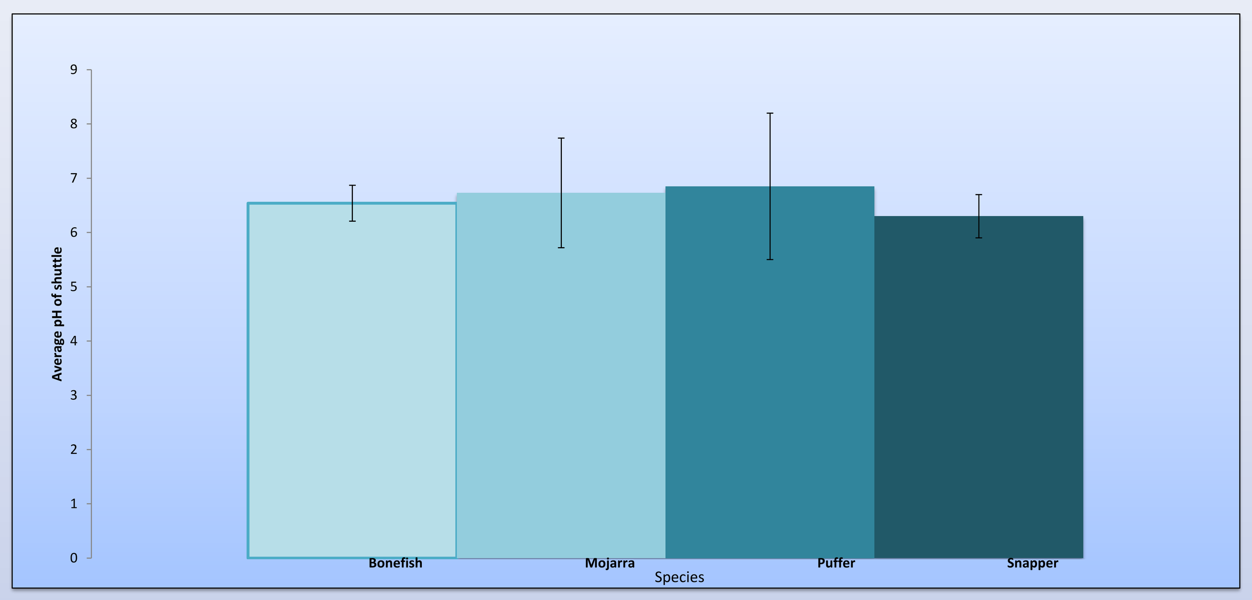

Fig. 5. The mean pH at the time of shuttle for bonefish, schoolmaster snapper, yellow-fin mojarra, and checkered puffer. The difference in the average pH between species was not significant (ANOVA, $p > 0.05$).

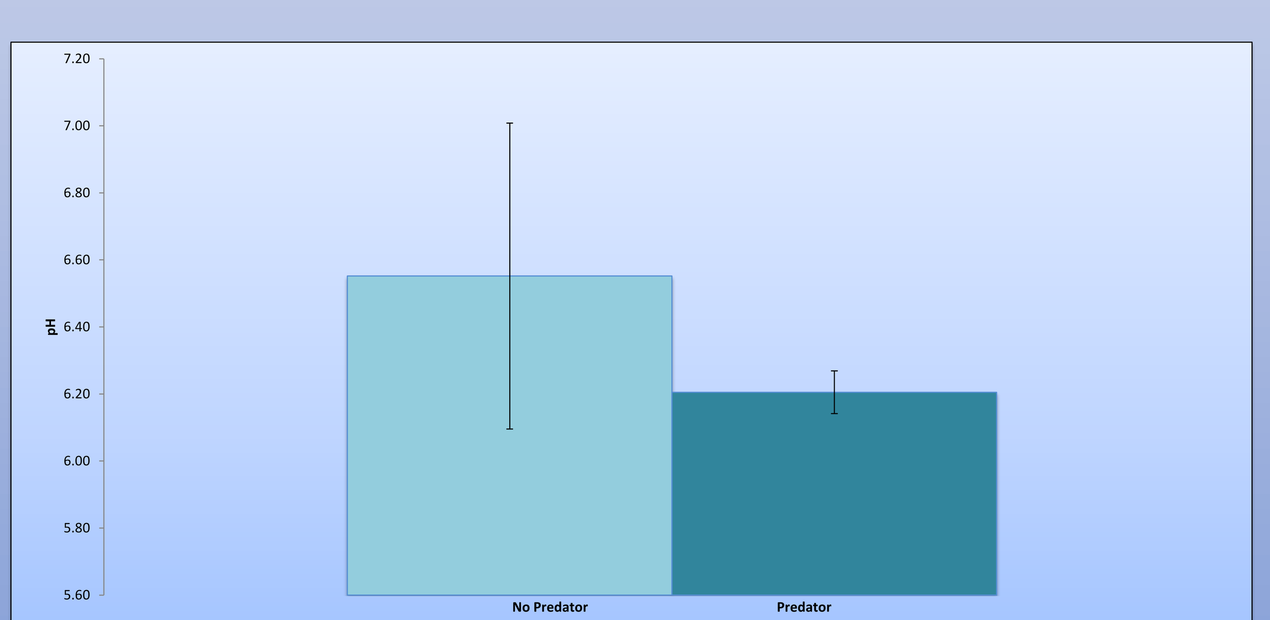

Fig. 6. The mean pH at which the Bonefish shuttled with and without a predator present. No significant difference was observed (T-test; $p > 0.05$)

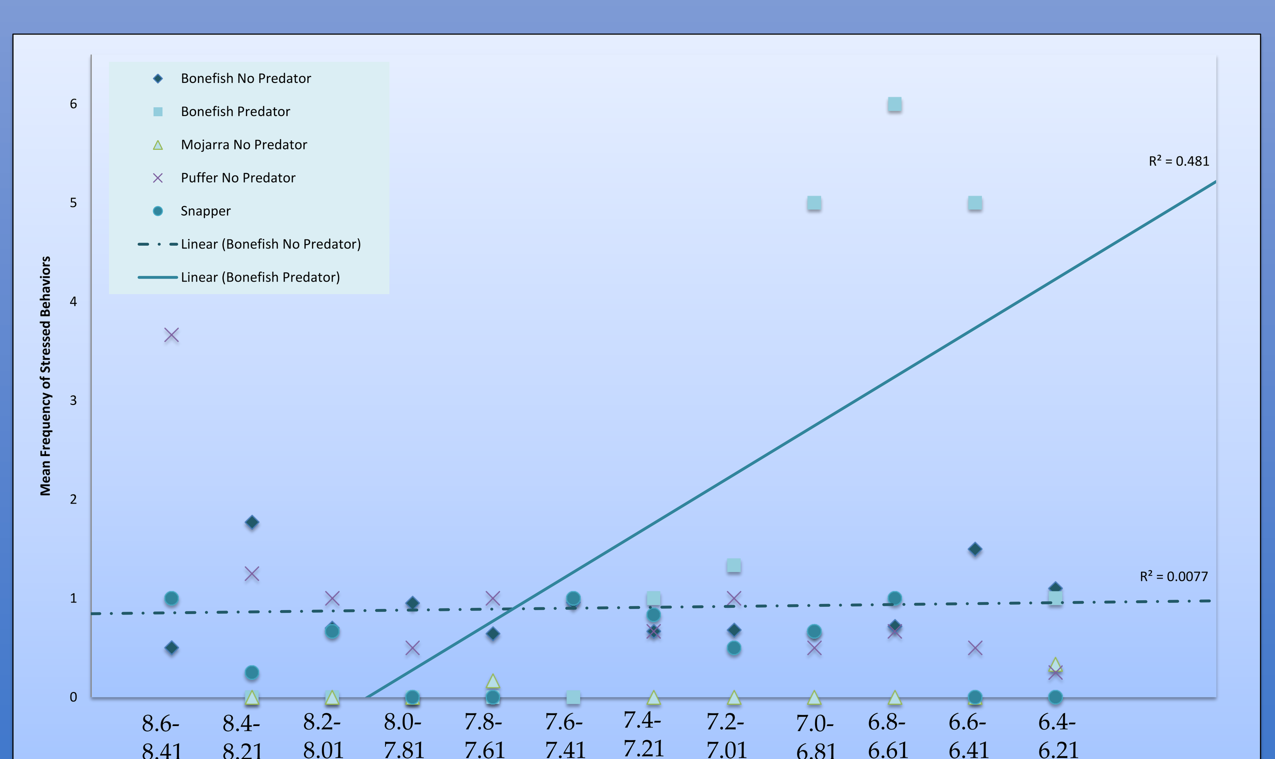

Fig. 7. The frequency of stressed behaviors at varying pH. The puffer exhibited a decrease in frequency of stressed behaviors as the pH decreased. The mojarra and snapper exhibited no change in the frequency of stressed behaviors. Regression lines demonstrate the increase of stressed behaviors in bonefish when a predator was present in the ambient shuttlebox tank.

Results

In the shuttlebox experiment, no significant difference was observed in the mean pH at which yellowfin mojarra, bonefish, schoolmaster snapper, or checkered puffer shuttled from the side of the shuttle box of decreasing pH to the ambient side (ANOVA, $p > 0.05$; Fig. 5). Additionally, no difference in the mean pH at which bonefish shuttled in controlled conditions versus when a predator was present in the ambient side was observed (T-test, $p = 0.31$; Fig. 6). All bonefish in the trial with a predator present lost equilibrium after shuttling.

An increase in the frequency of stressed behavior was observed in bonefish when a predator was present ($r^2 = 0.443$, Fig. 7). In trials without a predator, bonefish demonstrated an increase in stressed behaviors (e.g., gulping for air, unusual swimming patterns, rolling, and loss of equilibrium; Fig. 8b.) when compared to yellowfin mojarra, schoolmaster snapper, and checkered puffer.

A

B

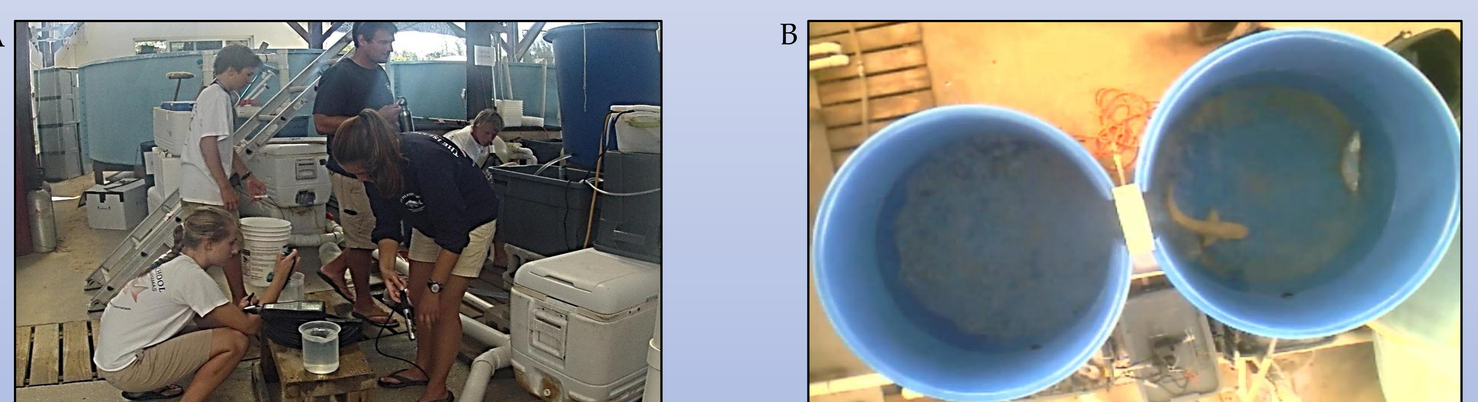

Fig. 8. Island School researchers measure pH during a shuttlebox experiment (A). A bonefish loses equilibrium following shuttling to the ambient tank during a predator trial (B).

Discussion

The results of the experiment demonstrate that a decrease in pH triggers a behavioral response in all four species tested. Also, all species searched for more favorable conditions at the same pH. This means that when pH in the ocean reaches the point when these species feel as though they must move, many populations of fish may migrate out of the mangroves at the same time. When a predator was present in the ambient tank of the shuttlebox, it was observed that the bonefish remained in the manipulated tank to a lower pH than in the non-predator trials, although this was not statistically significant. However, the sample size was small, so increasing the sample size may increase the statistical power of the difference in mean shuttle pHs. All of the bonefish in the predator trials remained in the manipulated tank long enough to lose equilibrium. This demonstrates that in the non-predator trials, bonefish were staying in the manipulated tank to a pH that is just before their critical pH, and when a predator is present, the bonefish's ability to maintain equilibrium is compromised.

Unlike the other three species, the bonefish demonstrated an increase in stressed behaviors – such as rolling, gasping for air, searching for an exit, and frantic swimming – as the pH decreased. With the presence of a predator, the bonefish demonstrated an even higher frequency of stressed behaviors in the manipulated tank before they lost equilibrium. In the wild, increased stressed behaviors may reduce feeding, growth and reproduction (Pörtner & Farrell 2008). This could result in bonefish migration if conditions continue to worsen, meaning the flats would lose a key member of their ecosystem. If the bonefish leave, it could result in a top-down trophic cascade. The effects of climate change could have negative ecological and economic effects in the Bahamas.

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